Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 13 (2012) 1003 – 1009

Procedia Environmental Sciences

The 18th Biennial Conference of International Society for Ecological Modelling

Water harvested from the air combined with solar power, shade and light providing system: conception of water-saving irrigation

G. F. Chen[a]*, D. S. Cai[a,b]

[a]*College of Hydraulic and Environmental Engineering, China Three Gorges University, Yichang, 443002, China*
[b]*Water Resources Department of Guangxi Zhuang Autonomous Region, Nanning,530023, China*

Abstract

In China, agriculture accounts for the largest proportion of water consumption. Analyzing the present water-saving irrigation situation, we propose to build a combined system. First, the system could use the farmland solar energy resource, transfer it into electricity, which will cover the wants of agricultural production and farmers' daily lives. Second, according to the crops' wants of sunlight, the system could adjust the light's strength and lasting time by providing shade and artificial light. Third, the system could harvest water from the air with bionic material structure, which will use the water resource circularly result in the improvement of water utilization efficiency.

Keywords: water-saving irrigation; bionic material; solar power; combined system

1. Introduction

In China, the problem of water resources shortage is outstanding, water resources per capita is far below the world average level. Meanwhile, a serious problem of water resources' uneven distribution exists. According to the Bulletin of Water Resources in China, 2008, the nationwide total water consumption is 591,000,000,000m^3, of which agricultural water consumption accounted for the great share of 62.0%—agriculture took the largest part in water consumption. From the Bulletin of Flood and Drought Disasters in China, 2009, the affected area by drought is 29,258,800hm^2, including 13,197,100

* Corresponding author. Tel.: 15572787231.
E-mail address: ice20051012@126.com

 doi:10.1016/j.proenv.2012.01.093

hm^2 disaster area, 3,268,800 hm^2 non-harvest area; 17,506,000 rural population and 10,994,000 livestock had to face the difficulty of drinking; 89 cities appeared shortage of water supply in different degrees successively. Following the development of national economy, the increasing of urban and rural population, the process of urbanization and the improvement of people's living standard, the demand for water will increase greatly. However, the environment of water resource deteriorates gradually and its total use efficiency is low. All of these will lead to the water supply and demand contradiction getting worse. Focus on the present situations, we can see that developing water-saving irrigation is an inevitable choice in building the resource-saving and environment-friendly social, and also in promoting the rational use of resources and changing the traditional resources use patterns.

Water-saving irrigation is an efficient water using model: people try to get as much produce as possible with the lowest water consumption. In China, great potential exists in the agricultural water-saving project. Table 1. shows the water consumption situations. To develop water-saving irrigation technology, people should consider all aspects of the whole irrigation process. Irrigation methods, technical measures, systems that can reduce the water loss, improve the water using efficiency are all in the category of water-saving irrigation technology[1]. Generally speaking, water-saving irrigation technology includes water-saving irrigation engineering technique, water-saving agricultural technique, water-saving management technique. Among them, water-saving irrigation engineering technique is the most important part, and it is also the key technique to ensure that the water-saving agriculture develops healthily[2].

Table 1. Water consumption situation

Year	Actual Irrigated Farmlands Consumed Water Per Mu	Nationwide Total Water Consumption	Percentage Of Agricultural Water Consumption
2005	$448m^3$	$563,300,000,000m^3$	63.6%
2006	$449m^3$	$579,500,000,000m^3$	63.2%
2007	$434m^3$	$581,900,000,000m^3$	61.9%
2008	$435m^3$	$591,000,000,000m^3$	62.0%

Cited from the Bulletin of Water Resources in China

2. Water-saving irrigation engineering technique

Water-saving irrigation engineering technique contains channel seepage control technique, pipeline water transfer technique, water-saving surface irrigation technique, sprinkler irrigation technique, drip irrigation technique and so on. Choose a reasonable engineering technique could be helpful to improve the benefit of water-saving agriculture[2]. We had chosen some popular techniques to be introduced as below.

2.1. Water-saving surface irrigation

Surface irrigation is the old technique in applying water to farmland, but it is widely adopted by countries all over the world especially the developing countries. In view of the reality in China that the water resource and energy are poor, the national economic strength is insufficient, the technical management level is low in vast rural areas, we could find that it is severely restrained to introduce sprinkler irrigation, drip irrigation and other advanced irrigation techniques in large area. So a long time in the future, we still need to intensify the constructions of farmland projects, study and generalize water-saving surface irrigation techniques vigorously. The main measures are supposed: 1, Level land, design

reasonable ditch (Fig. 1) and border check dimensions and technical parameters of irrigation. 2, Improve the moistening patterns of surface irrigation, develop the local moistening irrigation techniques. 3, Change the traditional patterns of discharging water to farmland, develop the intermittent irrigation. 4, Improve the ditch and border check water discharging facilities. 5, Develop the water-saving moisture conservation techniques, such as film hole irrigation technique.

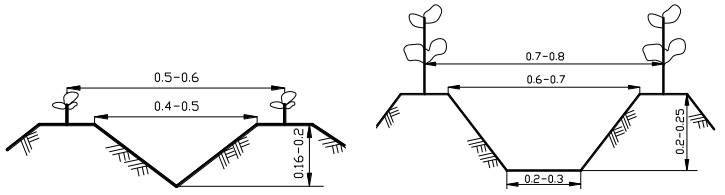

Fig.1. Certain ditch sections (unit: m) (a) triangle; (b) trapezoid

2.2. Sprinkler irrigation

Special pipeline systems and facilities are used in sprinkler irrigation work, with which the pressure water is transferred to the farmland and then sprayed into the air, forming numerous small droplets, which will fall and moisten the farmland. The obvious advantages of sprinkler irrigation are laid out: strong adaptability to terrain, accounting for litter land, high degree of mechanization, uniform irrigation. Owning to these advantages, it is commonly adopted for high permeability land, and it is also have the ability to adjust the air humidity and temperature. But it is also have the disadvantages like that greatly influenced by wind, high equipment investment. Since there are many kinds of sprinkler irrigation systems, its advantages and disadvantages vary considerably. In China, farmers often use fixed-pipeline sprinkler irrigation system, semi-fixed pipeline sprinkler irrigation system (Fig.2), movable sprinkler irrigation system. As we know different kinds have different advantages and disadvantages, we should choose the right kind according to the actual situations.

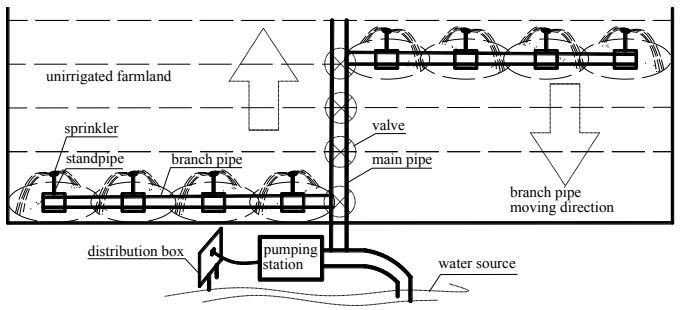

Fig.2. Semi-fixed pipeline sprinkler irrigation system

2.3. Drip irrigation

Drip irrigation systems often work with a series of low pressure pipes, with which the water will be transferred to the farmland. And the water will at last flow through the part that is named emitter. Because of the emitter's action, water will be formed into the formation of droplets, which will slowly, constantly, drip into the crop's root part. Literally, it works like the "intravenous drip", which will make the crop's

root part remain comfortable moisture. Owning to the dripping speed is less than the soil infiltration rate, surface runoff will not happen, the soil structure will never be destroyed, the soil will never be compacted, and the moisture, fertilizer, air, heat, microbial activities existed in the soil will always in the good conditions. All of which will create advantage conditions for the crop's high quality and high yield. What's more, the drip irrigation system can transfer fertilizer dissolved in the water to the crop at the same time. So it improves not only the efficiency of water using but also the efficiency of fertilizer using. Compared with the surface irrigation, the drip irrigation system can multiply the water-saving, and with the sprinkler irrigation system, it is also more scanty. But it has the same disadvantage of high cost and that of pipeline and emitter blocking. A certain type of drip irrigation system is shown in Fig. 3.

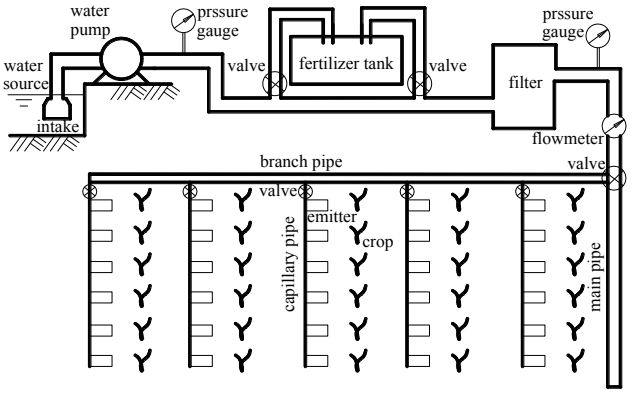

Fig.3. Drip irrigation system

3. Prospect of water-saving irrigation engineering technique

3.1. Technical background

In China, researchers often focus on four aspects in studying the water-saving technique[3]: 1, Adopt the pipelines and seepage control channels to transfer irrigation water efficiently: with which the water loss will be reduced in transfer result in the improvement of water transfer efficiency. 2, Develop the fine surface irrigation techniques and the farming techniques, which will full use the irrigation water, so that the loss of non-produce water will be reduced result in the water using efficiency improving.3, Study crops' genetic characteristics and water physiological mechanisms to cultivate, select and layout the drought- tolerance water-saving varieties, which will adjust its water production process result in the maximum using of water. 4, Develop the chemical substances, which will restrain the water contained in the soil from evaporating, promote the roots sucking water and reduce the transpiration intensity. Although all of these studies will be helpful for the water-saving irrigation project, they have ignored an important link: the use of moisture (crop transpiration, surface evaporation) contained in the air over the farmland.

Foreign scholars have done researches on harvesting water from the humid air. Some tried to congeal the air to collect water. According to S.L. Speetjens[4] et al., an experimental greenhouse, which owned a 10m height double walled tower and covered a ground area of 14×14m, had built in Almeria, Spain. It regained 70% of the irrigation water at the first tests show. Some focused on using certain bionic material to filter the humid air harvesting water. Dr. Jamal Sarsour[5] et al. had done some related researches (Fig. 4) and gained delightful achievements. The researches' achievements show that taking technique

measures to circularly utilize the water contained in the air (crop transpiration, surface evaporation) is fully feasible.

Fig. 4. (a) Fibre-based fog collector with adhered water droplet; (b) Field trials at desert station Gobabeb (Nami Desert), Namibi

3.2. Theoretical basis

Based on the water-saving irrigation achievements domestic and abroad and our own understanding on it, we propose building a combined system: water harvested from the air combined with solar power, shade and light providing irrigation system. The combined system rests on five main principles: crop transpiration, water evaporation, energy conversion, bionic water colleting, water-saving irrigation.

3.2.1. Crop transpiration and water evaporation principles

Usually, the majority irrigation water will be evaporated into the air from the earth's surface, only a small portion will be absorbed by the crops. What's more, large part of the small portion will also flee into the air through the transpiration action. So, we can see that there is large amount of water contained in the air that could be regained−it is the base of our conceiving system.

3.2.2. Energy conversion principle

Our conceiving system will make use of field solar energy and convert it into electric energy, which will provide the system with power. As we know, the produce will be affected by the local sunlight's strength and lasting time. So for high quality and high yield, we need to make the crops under optimum growth states—with sufficient artificial light and comfortable temperature. Both of them will be fitted by the power generation part. At the same time, the left electric energy can be provided for the farmers' daily life.

3.2.3. Bionic water colleting principle

Many biological surfaces, both the plant and animal kingdom, possess unusual structural features at the micro and nanometer scale— they could capture water for their daily life all by themselves[6]. An interesting example is provided by desert beetles, which use micrometre-sized area of hydrophobic and hydrophilic on their backs to capture water from humid air. Another, as anyone admired spider webs adorned with dew drops will appreciate spider silk's ability of capturing water from air. Similarly, many kinds of insects' wings', plants' villus and other special biological structures have the ability to capture water from the air. Their special ability has aroused people's attention. Researchers try to imitate them and produce materials with the same ability, which could be provided for the water shortage areas to capture water from the air for drinking and irrigation.

3.2.4. Water-saving irrigation principle

As we know, crops at different life stages have different wants of water, so we should irrigate crops timely with satisfied water under the help of irrigation system. In that case, we could achieve the aim of

having a high quality harvest—less water, more harvest. Water-saving irrigation is a necessary measure on the way of changing the traditional agriculture to the high quality, high yield, high efficiency modern agriculture.

3.3. Structure explanation

The conceiving system (Fig. 5) consists of two main parts: the water-capturing water-saving irrigation part, the power part. Crops' transpiration action and water evaporated from earth's surface provide the biomimetic water-capturing materials with humid air. Biomimetic materials will filter the humid air: through which the water contained in the humid air will be intercepted and then flow into the water container for later use—when the moisture detector turns out that the soil wants water, the irrigation system will be turned on. The biomimetic materials' efficiency of capturing water from the air most decide the system's economic benefit. Solar panels are first designed to absorb sunlight producing electricity—the solar panels could be rotate in all directions for the purposes of absorbing sunlight to the maximum and not affecting the crops accepting sunlight. Second, they could be used to collect rainwater: raindrops fall on its surface and then flow into the water container. Third, when the strength of sunlight exceed crops' wants, we can adjust the direction of solar panels to provide shade for crops. In order to save the cost, we could take certain material for shading only to replace the solar panels when the system is largely used.

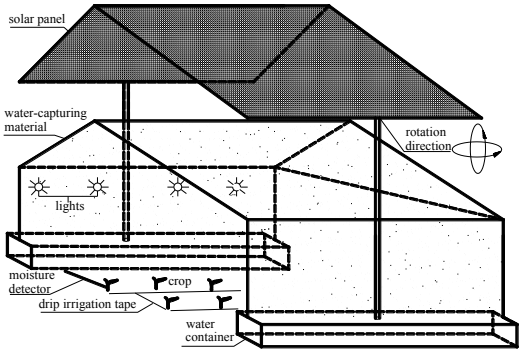

Fig.5. Conceiving system

As we know crops at different growth stages want different strength and lasting time of sunlight: the strength and lasting time of sunlight have a strong influence on the crop (Table 2) [7]. However, the wants often are restrained by local climate and weather, now our conceiving system can figure it out. When the sunlight is insufficient, such as during the endless raining days, the nights, we could turn on the lights to cover crops' wants. The heating could also be provided by the system if crops want.

Table 2. Influence of different strength and lasting time of sunlight on chlorophyll content of honey dew seedling (mg/g)

Condition		Chlorophyll-a	Chlorophyll-b	Carotenoid	Total Chlorophyll
Strength	100%	1.1903	0.3431	0.3020	1.5334
	80%	1.1584	0.3413	0.2851	1.4997
	60%	1.1550	0.3234	0.2780	1.4784
Time	16h	1.4389	0.4355	0.3714	1.8744
	12h	1.4250	0.4309	0.3582	1.8559
	8h	1.3723	0.3955	0.3546	1.7678

In summary, the successful development of our conceiving system will not only a big progress in the water-saving irrigation technique, but also a big progress in promoting crops' high quality and high yield.

4. Conclusions

In China, the deteriorated water environment and low use efficiency of water now are supposed to be the important constraints of national economic development and social sustainable development. Therefore, it has a special significance to intensely develop and spread advanced water-saving irrigation techniques.

The electricity shortage also has happened in many cities. Since the conceiving system uses farmland solar energy, it will reduce the agricultural electricity consumption. At the same time, the sufficient produced electricity could be provided for farmers' daily lives. So it may relieve the situation of electric insecurity. Developing farmland solar energy will also change the farmland's traditional using pattern: from the single using pattern to the dualistic pattern, which will increase the farmland's profits.

The technique of water harvested from the air has broken through the traditional water-saving patterns. It is endowed with incomparable advantages, especially used in the arid and semi-arid areas. If the technique is introduced to circularly use the water resource with high efficiency, it will play an important part in protecting the ecological environment and developing the agricultural production.

Many problems needed to be solved exist in the conceiving system, and some of them maybe very complex. For the system is a combined project, multi-disciplinary researches are required in the study. With the development of all concerned subjects, we suppose the system will be achieved one day.

Acknowledgements

Many references had to be deleted to shorten the paper, and we apologize to authors and readers for work that could not be cited. We thank researchers' previous studies for enlightening us to write this paper. We thank Master Wang Qing and Yang Le for enlightening discussions.

References

[1] Cui Y. *Agricultural Water-Saving Thecnology and Application Examples.* Beijing: Chemical Industry Press, 2005. (in Chinese)

[2] Gao CC, Wu P. *Irrigation Project Water-Saving Theory and Technology*. Zhengzhou: Yellow River Conservancy Press, 2005. (in Chinese)

[3] Gong DZ, Hao WP, Mei XR. Condensing evapotranspiration for irrigation based on heat exchange and bionics for collecting liquid water. *Transactions of the CSAE*, 2010;**26**: 8–12. (in Chinese)

[4] Speetjens SL, Stigter JD, van Straten G. Physics-based model for a water-saving greenhouse. *Biosystems Engineering*, 2010;**105**: 149–59.

[5] Sarsour J, Stegmaier T, Linke M, Planck H. Bionic development of textile materials for harvesting water from fog. 5th International Conference on Fog, Fog Collection and Dew, Münster, Germany, 2010 pp. 1–4.

[6] Zheng YM, Hao B, Huang ZB, Tian XL, Nie FQ, Zhao Y, Zhai J, Jiang L. Directional water collection on wetted spider silk. *Nature*, 2010;**463**: 640–3.

[7] Li SD. The effects of different light and temperature on the growth and physiology characteristics of muskmelon seedling. Master Thesis, ShaanXi, China: Northwest A&F University, 2007. (in Chinese)